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Physiological quality of oat (*Avena sativa* L.) seeds cultivars under different storage conditions

Qualidade fisiológica de sementes de cultivares de aveia granífera (*Avena sativa* L.) em diferentes condições de armazenagem

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Highlights

Oat seed quality was compared under cold chamber and conventional storage.
Conventional storage reduced vigor and seedling dry mass after four months.
URS Corona was more sensitive to storage than IPR Afrodite and IPR Andrômeda.

Abstract

Proper seed storage is essential for maintaining seed viability and vigor over time. Due to limited information available on *Avena sativa* L., this study aimed to evaluate the physiological quality of oat seeds stored under two conditions over 8 months. Seeds of the cultivars IPR Afrodite, IPR Andrômeda, and URS Corona were stored in big bags under conventional warehouse conditions and in paper bags under cold chamber conditions. Sampling was conducted every 2 months to determine moisture content, thousand-seed weight, germination, first germination count, shoot length, root length, shoot dry mass, root dry mass, emergence speed index, seedling emergence in sand, electrical conductivity, and accelerated aging. The experimental design was completely randomized, and the data were subjected to a combined analysis of variance between storage environments. When significant, regression analysis was performed for variables as a function of storage time. Standardized data were further analyzed using multivariate principal component analysis. The results indicated that the two storage environments did not significantly affect germination or seedling emergence in sand. However, a reduction in seed vigor was observed for the cultivars URS Corona and IPR Afrodite, along with a decrease in seedling dry mass from the fourth month of storage under conventional warehouse conditions. Germination of the cultivar

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URS Corona declined over time, whereas the cultivars IPR Afrodite and IPR Andrômeda maintained their viability throughout the storage period.
Key words: White oat. Cold chamber. Seed vigor.

Resumo

O armazenamento adequado de sementes é essencial na manutenção da sua viabilidade e vigor ao longo do tempo. Devido à falta de informações para a *Avena sativa* L., o objetivo deste estudo foi avaliar a qualidade fisiológica de sementes de aveia granífera submetidas a duas condições de armazenagem por um período de oito meses. As sementes das cultivares IPR Afrodite, IPR Andrômeda e URS Corona foram armazenadas em big bags no armazém convencional e em sacos de papel na câmara fria. A cada dois meses foram realizadas amostragens para determinação do teor de água, peso de mil sementes, germinação, primeira contagem da germinação, comprimento e massa seca de plântulas, índice de velocidade de emergência, emergência em areia, condutividade elétrica e envelhecimento acelerado. O delineamento experimental foi inteiramente casualizado, e os dados foram submetidos à análise de variância conjunta entre os ambientes. Quando significativa, procedeu-se à análise de regressão para as variáveis em função do tempo de armazenamento. Os dados padronizados foram submetidos à análise multivariada por componentes principais. Os resultados indicaram que os dois ambientes de armazenamento não influenciaram significativamente a germinação nem a emergência em areia. No entanto, observou-se redução no vigor das cultivares URS Corona e IPR Afrodite, bem como perda de matéria seca a partir do quarto mês de armazenamento no armazém convencional. A germinação da cultivar URS Corona foi negativamente afetada ao longo do tempo, enquanto as cultivares IPR Afrodite e IPR Andrômeda mantiveram sua viabilidade.
Palavras-chave: Aveia branca. Câmara fria. Vigor de sementes.

Introduction

Among the oat species cultivated worldwide, white oat (*Avena sativa* L.) is the most widely grown, highlighting its economic and agronomic importance. This species is highly versatile, being used for human consumption due to the nutritional quality of its grains, which are rich in functional compounds, as well as for animal feed in the form of hay, silage, green forage, and feed ingredients (Howarth et al., 2021). In southern Brazil and in regions of southeastern and central-western Brazil, the crop is also extensively cultivated for grain production and for generating crop residue used as soil cover, particularly in no-tillage systems, thereby contributing to the sustainability of agricultural production systems (Fernandes et al., 2024).

Given the agronomic importance and wide range of uses of this crop, the production of high-quality seeds is a key factor for successful crop establishment and the full expression of crop yield potential. In this context, seed quality is associated with a set of genetic, physical, physiological, and sanitary attributes that determine its suitability for sowing. The storage potential of seeds from a given species or cultivar

depends on factors related to initial seed quality and the environmental conditions during storage (Meneguzzo, 2022). As a living organism, the seed requires appropriate storage conditions to maintain its viability and vigor. Inadequate storage conditions can accelerate deterioration, leading to reduced physiological quality, lower germination, and poorer seedling performance, underscoring the importance of evaluating different storage systems for their effectiveness in maintaining seed quality (Kaefer et al., 2019).

Regardless of the species being produced, the attainment, maintenance, and assessment of seed quality should remain constant concerns for seed producers. Although seed quality is primarily established in the field, its preservation until the subsequent growing season depends on the adoption of appropriate post-harvest technologies (Peske et al., 2012). Seed deterioration is an inevitable and irreversible process; however, its rate can be slowed by controlling environmental conditions, particularly temperature and humidity, during storage (Baudet & Villela, 2019).

Despite the importance of grain oat cultivation, there remains a scientific gap in understanding the physiological behavior of its seeds under different storage conditions. Many of the available technical recommendations are still based on extrapolations from other winter cereal species, overlooking potential oat-specific characteristics and limiting the establishment of storage standards tailored to this crop.

In light of this, the present study is justified by the need to understand how different storage conditions affect the quality of oat seeds during the off-season. Given that factors such as temperature, relative humidity, and packaging type directly affect seed deterioration rates, it is essential to identify efficient storage strategies that preserve seed physiological potential, thereby ensuring proper crop establishment and productive performance in the subsequent growing season.

Material and Methods

The present study was conducted in partnership with SL Cereais e Alimentos, located in Mauá da Serra, Paraná State, Brazil, during 2022 and 2023. Grain oat seeds of the cultivars IPR Afrodite, IPR Andrômeda, and URS Corona were received at the seed processing facility of SL Alimentos. Seed processing was carried out from November 2022 to January 2023, and the seeds were packaged in big bags with an approximate capacity of 600 kg. A separate lot was maintained for each cultivar to allow periodic sampling, which was conducted every 2 months over a total storage period of 8 months.

Samples from these lots were collected, packaged in kraft paper bags, and stored under controlled temperature and humidity conditions in a cold chamber at the Seed Processing Unit of the Instituto de Desenvolvimento Rural do Paraná – IAPAR-EMATER (IDR-Paraná), located in Londrina, Paraná State, Brazil. The remaining seeds from each lot were kept in the original big bags and stored in a conventional warehouse at the SL Alimentos facility in Tamarana, Paraná State, Brazil, where they were exposed to ambient temperature and relative humidity conditions within the storage facility.

Storage began in January 2023, and the seeds remained stored until August 2023. The average temperature and relative humidity data recorded in the cold chamber and in the conventional warehouse without environmental control are presented in Figure 1.

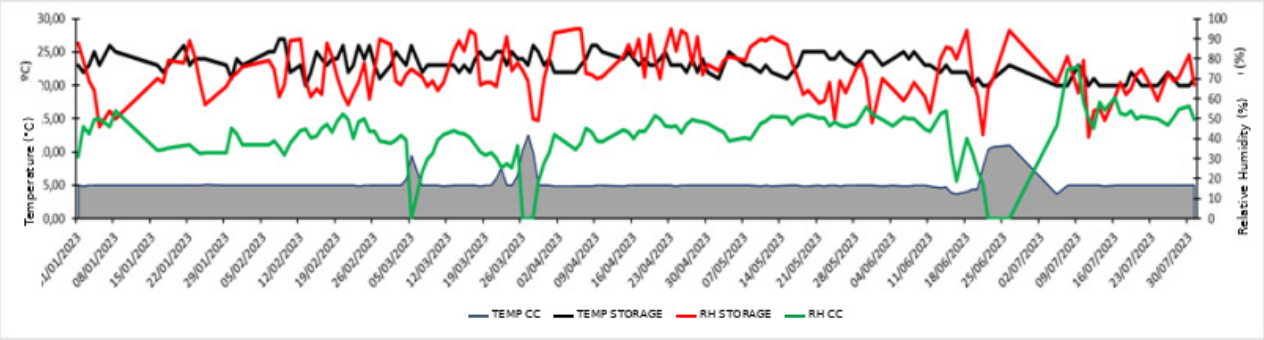


Figure 1. Temperature (TEMP, °C) and relative humidity (RH, %) in the cold chamber (CC) and conventional warehouse (CW) environments during the storage of grain oat seeds.

Sampling from the big bags was performed using grain sampling triers at each collection period. The Kraft paper bags were homogenized, and the seeds were divided into individual packages so that, at each sampling date, one package was collected and taken to the laboratory for analysis.

The physiological quality assessments were conducted at the Seed Laboratory of IDR-Paraná, located in Londrina, Paraná State, Brazil. The following analyses were performed:

i. **Moisture content:** determined using the oven-drying method at 105 ± 3 °C for 24 h, with two replicates of 100 seeds each (Ministério da Agricultura e Pecuária [MAPA], 2009). Results were expressed as a percentage.

ii. **Thousand-seed weight:** determined by counting and weighing eight replicates of 100 seeds. The mean value obtained was multiplied by ten to estimate thousand-seed weight, expressed in grams (MAPA, 2009).

iii. **Germination test and first germination count:** performed using four replicates of 50 seeds placed in rolls of germination paper moistened with water at a volume equivalent to 2.5 times the dry weight of the substrate. The rolls were maintained in a germinator at 20 °C for seven days. Evaluations were conducted at two assessment dates: four days after test setup (first germination count – FGC) and seven days after test setup (final

germination – G), and the percentages of normal, abnormal, and dead seeds were recorded (MAPA, 2009). Results were expressed as percentages.

iv. **Shoot and root length:** determined using five replicates of 20 seeds sown in the upper third of germination paper moistened with water at a volume equivalent to 2.5 times the dry weight of the paper. The rolls were maintained in a germinator at 20 °C for four days. Subsequently, the shoot and root lengths of normal seedlings were measured using a graduated ruler. Mean shoot and root lengths were obtained by summing the measurements recorded in each replicate and dividing by the number of normal seedlings, with results expressed in centimeters per seedling (Krzyzanowski et al., 2020).

v. **Seedling dry mass:** the shoots and roots of normal seedlings obtained from the shoot and root length test were excised and separated from the remaining seed tissues (seed reserves), placed in paper bags, and dried in a forced-air oven at 80 °C for 24 h. After this period, dry mass was determined using a balance with a precision of 0.001 g, and the results were expressed as grams per seedling (Krzyzanowski et al., 2020).

vi. **Sand emergence and emergence speed index:** conducted under greenhouse conditions using eight replicates of 25 seeds sown in plastic trays containing previously washed, sieved, and sterilized sand. At sowing, the seeds were covered with a 3-cm layer of sand maintained at 60% of its maximum water-holding capacity, with daily irrigation. The number of emerged seedlings was recorded daily for 15 days. Seedling emergence percentage was determined on the 15th day after test establishment. The emergence speed index (ESI) was calculated according to the equation proposed by Krzyzanowski et al. (2020).

vii. **Electrical conductivity test:** four replicates of 50 physically pure seeds were evaluated. The seeds were weighed to the nearest 0.01 g, immersed in 75 mL of distilled water, and maintained in a germinator at 25 °C for 24 h. After this period, the electrical conductivity of the soaking solution was measured using a GEHAKA CG 2000 conductivity meter. Results were expressed as $\mu S\ cm^{-1}\ g^{-1}$ (Vieira & Marcos Filho, 2020).

viii. **Accelerated aging test:** seeds were distributed in a single layer on stainless-steel screens placed inside plastic boxes (11.0 × 11.0 × 3.5 cm) containing 40 mL of water at the bottom. The closed boxes were maintained in a BOD chamber at 40 °C for 24 h. After the aging period, four subsamples of 50 seeds per replicate from each lot were subjected to the germination test according to the methodology previously described, with evaluation performed on the fifth day after test establishment (Marcos Filho, 2020).

The experimental design was completely randomized, and the collected data were subjected to a combined analysis of variance across storage environments (cold chamber and conventional warehouse) and storage periods (0, 2, 4, 6, and 8 months), with each cultivar analyzed separately. The experiments were evaluated for homogeneity of variance using the ratio of the largest to the smallest residual mean squares. Ratios lower than 7 were considered indicative of homogeneous experiments. When the treatment × experiment interaction was significant, even under homogeneous conditions, analyses were performed separately for each experiment using the pooled residual mean square from the combined analysis. The assumptions of normality of errors and homogeneity of variances were assessed using the Shapiro–Wilk and Bartlett tests, respectively, at the 5% significance level. All statistical analyses were performed using R (R Core Team, 2023) and the AgroR and AgroReg packages (Shimizu & Gonçalves, 2023).

Results

IPR Afrodite cultivar

In the analysis of variance, the ratio between the residual mean squares exceeded 7 for moisture content (MC) and root dry mass (RDM), indicating residual heterogeneity. Therefore, these variables were analyzed separately, following Barbin's (2003) methodological recommendations. For the remaining variables with ratios below 7, a combined analysis across storage environments was performed.

In the evaluation of seed physiological quality, the results of the germination, first germination count, seedling emergence, and emergence speed index tests showed no significant effects of storage environment or storage period (Table 1). Notably, the seeds exhibited high physiological potential, with germination exceeding 95% and vigor levels above 90% throughout the experimental period.

Table 1
Mean values for first germination count (FGC, %), germination (GERM, %), seedling emergence (SE, %), and emergence speed index (ESI) of seeds from the cultivar IPR Afrodite stored under cold chamber (CC) and conventional warehouse (CW) conditions for eight months

Afrodite	FGC	GERM	SE	ESI
		Environment		
CC	96.70	97.00	93.05	8.23
CW	95.90	96.10	92.35	8.22
		Time (Months)		
0	97.50	97.50	93.05	8.45
2	97.50	98.75	91.50	8.26
4	94.50	94.50	90.50	8.07
6	97.25	97.25	94.25	8.19
8	94.75	94.75	94.20	8.16

Among the variables evaluated, the isolated effect of storage period increased both shoot and root length up to the fourth month of storage, followed by a declining trend until the end of the experimental period, for both shoot length (Figure 2A) and root length (Figure 2B). A similar pattern was observed for shoot and root dry mass, which increased until the fourth month and subsequently declined (Figures 2C and 2D). However, these variables consistently showed higher values under cold-chamber (CC) storage conditions.

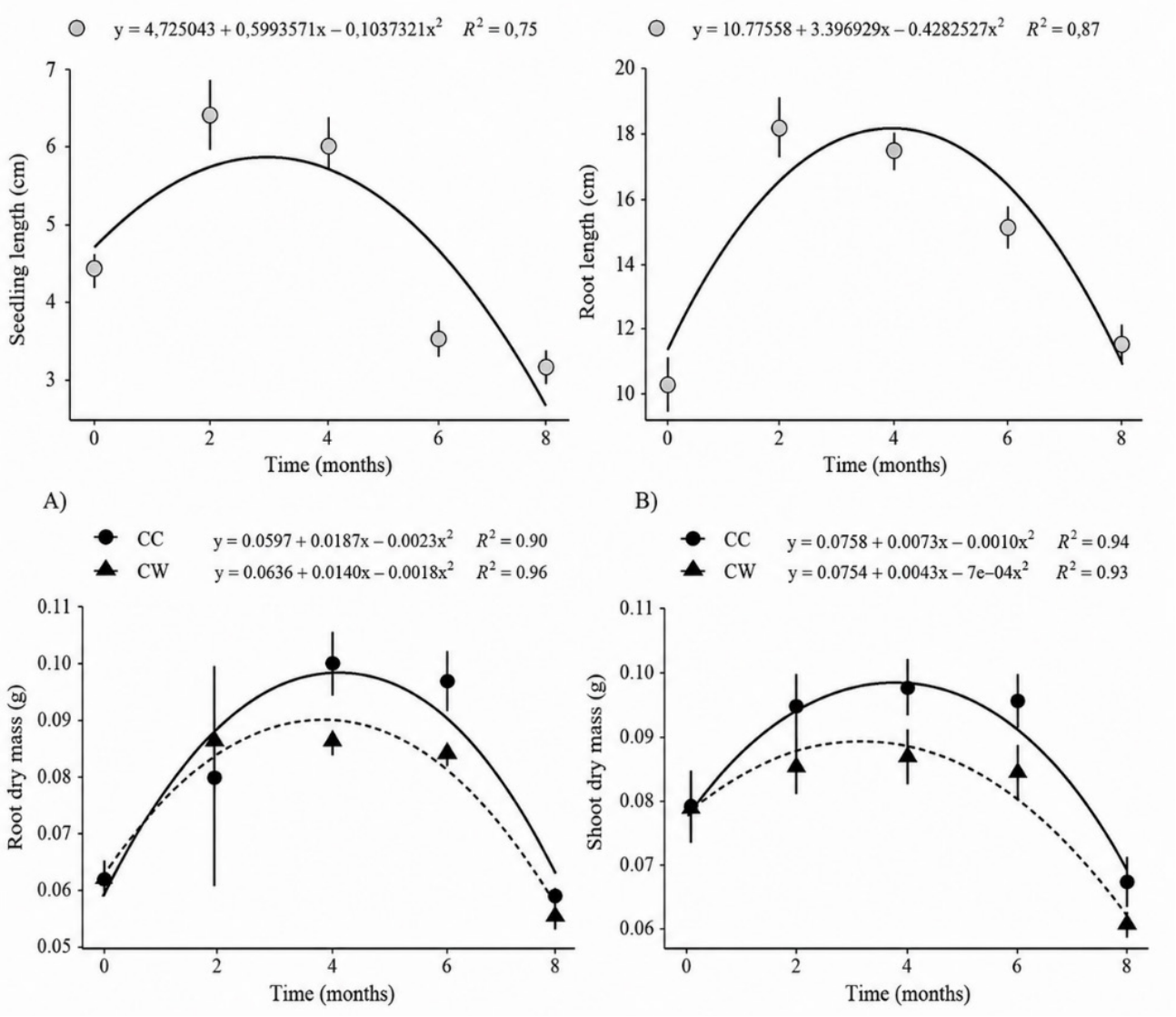


Figure 2. Shoot length (A) and root length (B) (cm seedling⁻¹), and root dry mass (C) and shoot dry mass (D) (mg seedling⁻¹) of grain oat seeds of the cultivar IPR Afrodite stored under cold chamber (CC) and conventional warehouse (CW) conditions for eight months.

A significant interaction between storage environment and storage period was observed for moisture content, accelerated aging, thousand-seed weight, and electrical conductivity. Moisture content exhibited distinct patterns across storage environments. Under cold chamber storage (CC), an initial reduction was observed, followed by an increase from the sixth month onward. In contrast, under conventional warehouse storage (CW), moisture content increased up to the fourth month, followed by a subsequent decline (Figure 3A).

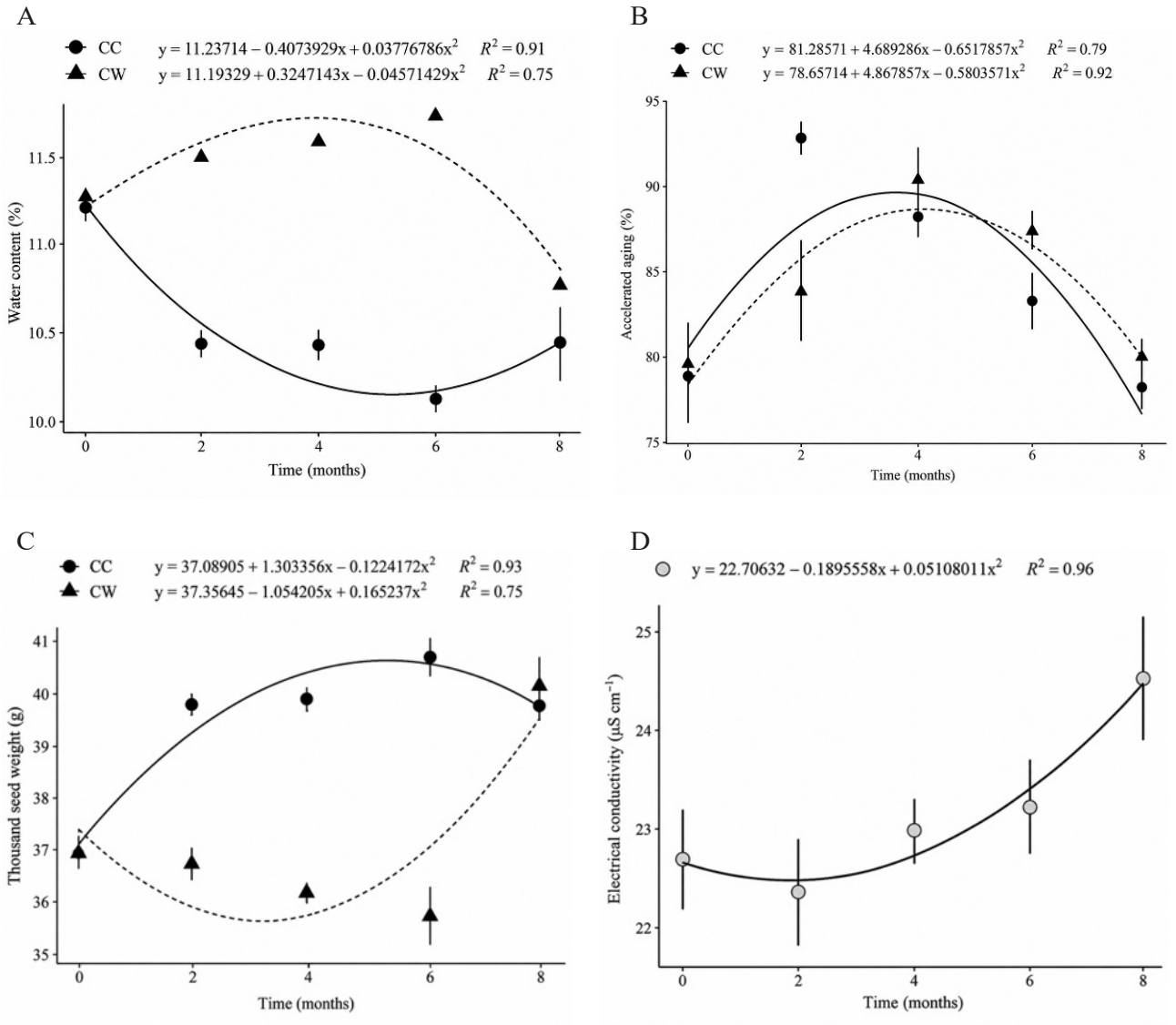


Figure 3. Moisture content (%) (A), accelerated aging (%) (B), thousand-seed weight (g) (C), and electrical conductivity (EC) (µS cm^{-1} g^{-1}) (D) of grain oat seeds of the cultivar IPR Afrodite stored under cold chamber (CC) and conventional warehouse (CW) conditions for eight months.

In the accelerated-aging test, both storage environments showed similar patterns, with a reduction in vigor observed at 4 months of storage. Although CC provided higher values during this initial period, CW showed superior performance thereafter (Figure 3B). Thousand-seed weight increased throughout the storage period under CC conditions. In contrast, under CW conditions, a progressive reduction was observed until the sixth month of storage. The value recorded at the eighth month was considered discrepant (an outlier) and was not representative of the overall data trend (Figure 3C). Electrical conductivity increased continuously in seeds stored under CW conditions, indicating progression of the deterioration process, whereas values remained stable over time under CC conditions; therefore, these data were not presented in Figure 3D.

IPR Andrômeda cultivar

For this cultivar, moisture content and electrical conductivity showed a residual mean-squares ratio greater than 7 in the analysis of variance; therefore, these variables were analyzed separately, whereas the remaining variables were evaluated in a combined analysis across storage environments. For moisture content, a significant environment × storage period interaction was observed only under CW conditions. Moisture content remained stable until approximately 2 months of storage, then increased significantly from the fourth month onward (Figure 4A). For electrical conductivity, a significant effect was detected only for the CW environment, with values increasing throughout the storage period (Figure 4B).

For the first germination count, germination, accelerated aging, emergence speed index, and root length tests, no significant effects of storage environment or storage period were observed, nor was there a significant interaction between these factors (Table 2). This behavior, similar to that observed for the cultivar IPR Afrodite, indicates the maintenance of seed physiological stability throughout the storage period.

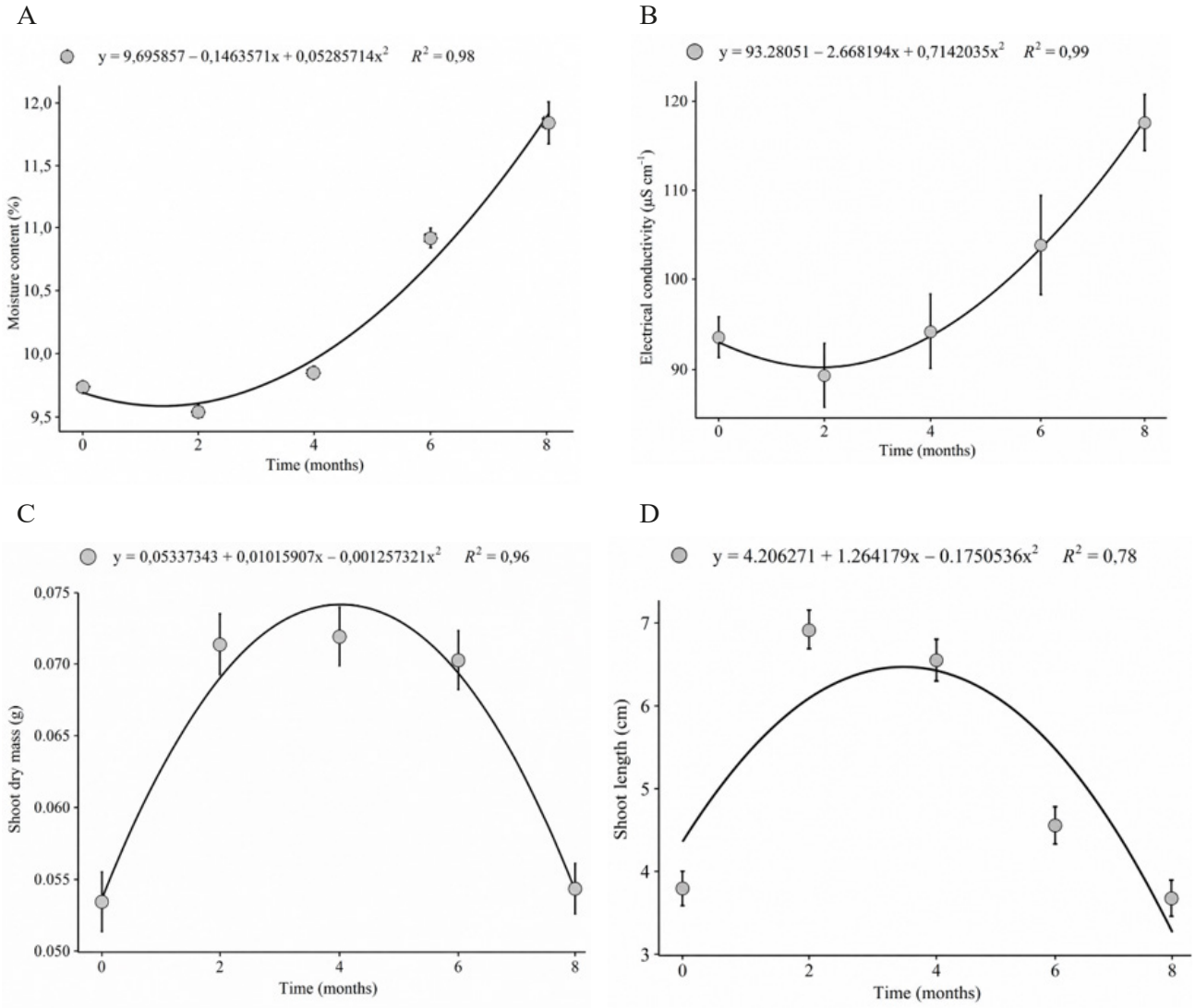


Figure 4. Moisture content (%) (A), electrical conductivity (EC, µS cm⁻¹ g⁻¹) (B), shoot length (cm seedling⁻¹) (C), shoot dry mass (g seedling⁻¹) (D), and root dry mass (g seedling⁻¹) (E) of grain oat seeds of the cultivar IPR Andrômeda stored under conventional warehouse conditions (CW) for eight months.

Table 2
Mean values for first germination count (FGC, %), germination (GERM, %), accelerated aging (AA, %), emergence speed index (ESI), and root length (RL, cm) of seeds from the cultivar IPR Andrômeda

	FGC	GERM	AA	ESI	RL
Environment					
CC	88.90	91.90	79.50	8.02	14.54
CW	86.20	88.70	79.10	7.70	11.32
Time (Months)					
0	91.50	91.50	81.00	8.40	15.70
2	79.75	93.50	78.50	8.01	15.41
4	88.50	88.50	81.75	7.77	13.97
6	88.75	88.75	78.75	7.72	11.99
8	89.25	89.25	76.50	7.40	17.60

Shoot length and seedling dry mass were influenced solely by storage period, with reductions from the fourth month onward and a continued decline through the end of the storage period (Figures 4C, 4D, and 4E).

Seedling emergence and thousand-seed weight showed significant interactions with storage environment and storage period. Seedling emergence showed a linear response, with slight variation across the eight months of storage, but only under CW conditions (Figure 5A). Thousand-seed weight showed contrasting responses between storage environments. Under CW conditions, a continuous reduction was observed from the beginning of storage, whereas under CC conditions, a gradual increase occurred throughout the storage period (Figure 5B).

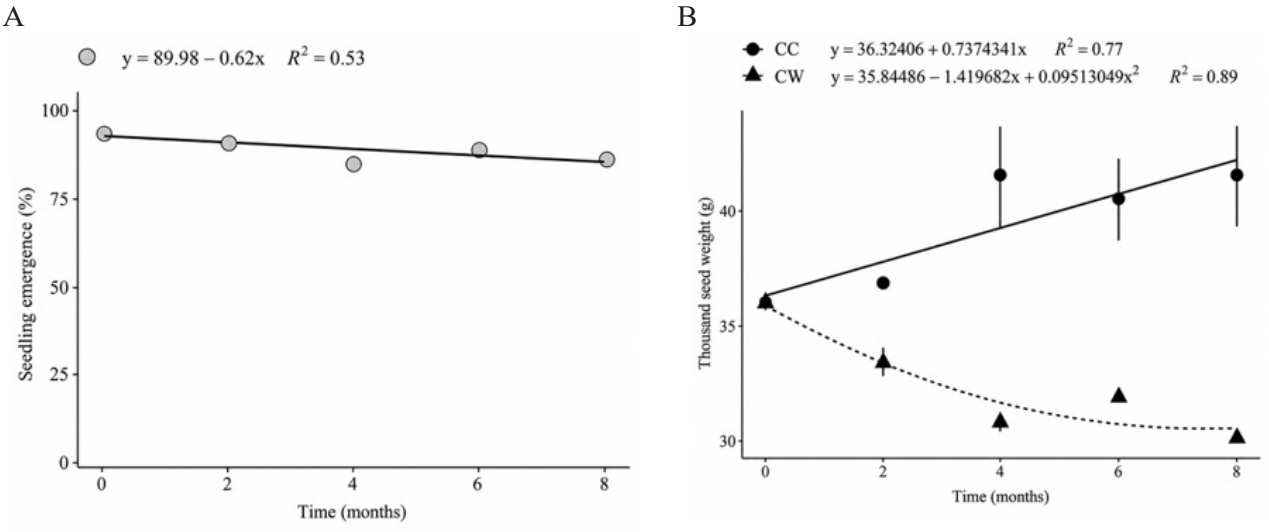


Figure 5. Seedling emergence (%) (A) and thousand-seed weight (g) (B) of grain oat seeds of the cultivar IPR Andrômeda stored under conventional warehouse (CW) and cold chamber (CC) conditions for eight months.

URS Corona cultivar

Among the evaluated tests, only moisture content and root dry mass exhibited a residual mean square ratio greater than 7 and were therefore analyzed separately. Moisture content showed a significant interaction between storage environment and storage period. Under CC conditions, a linear decrease in moisture content was observed throughout the storage period, whereas under CW conditions, moisture content increased until the fourth month and subsequently declined (Figure 6A). Root dry mass showed significant isolated effects of storage environment and storage period, with significant responses observed only under CW conditions, characterized by an initial increase up to the fourth month, followed by a subsequent reduction (Figure 6B).

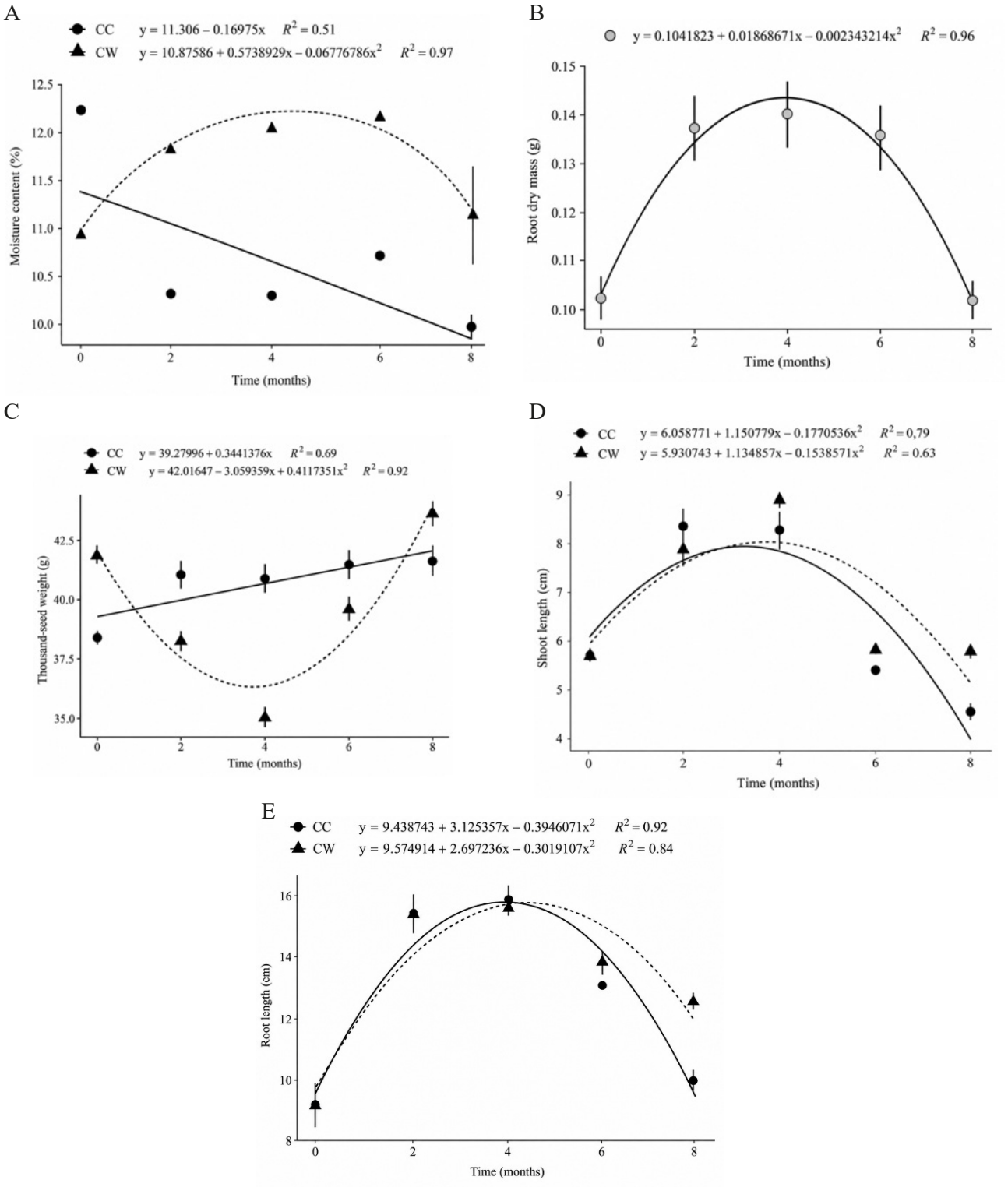


Figure 6. Moisture content (%) (A), root dry mass (g seedling⁻¹) (B), thousand-seed weight (g) (C), shoot length (cm seedling⁻¹) (D), and root length (cm seedling⁻¹) (E) of grain oat seeds of the cultivar URS Corona stored under conventional warehouse (CW) and cold chamber (CC) conditions for eight months.

In the combined analysis across storage environments, electrical conductivity, emergence speed index, and shoot dry mass showed no significant effects of storage environment or storage period, nor was a significant interaction observed between these factors (Table 3).

Table 3
Mean values for electrical conductivity (EC, μS cm^{-1} g^{-1}), emergence speed index (ESI), and shoot dry mass (SDM, g seedling^{-1}) of seeds from the cultivar URS Corona stored under cold chamber and conventional warehouse conditions for eight months

	EC	ESI	SDM
Environment			
CC	156.31	7.49	0.06
CW	158.82	7.12	0.06
Time (Months)			
0	152.12	7.55	0.05
2	152.67	7.35	0.06
4	151.25	6.90	0.06
6	157.54	7.67	0.06
8	154.25	7.05	0.05

A significant interaction between storage environment and storage period was observed for thousand-seed weight and shoot and root length. Thousand-seed weight showed distinct responses across storage environments. Under CC conditions, it increased continuously throughout the storage period, whereas under CW conditions, it decreased until the fourth month, then recovered (Figure 6C). Shoot length increased until the fourth month and subsequently declined in both storage environments, with final values slightly higher under CW conditions (Figure 6D). Root length increased up to the fourth month under CC conditions, then declined progressively. Under CW conditions, a similar pattern was observed; however, the increase extended until approximately the sixth month of storage (Figure 6E).

The germination, accelerated aging, and seedling emergence tests showed significant effects only for storage period, with linear responses characterized by declines in these attributes over time (Figures 7A, 7B, and 7C). It is noteworthy that germination remained above 90% even after eight months of storage.

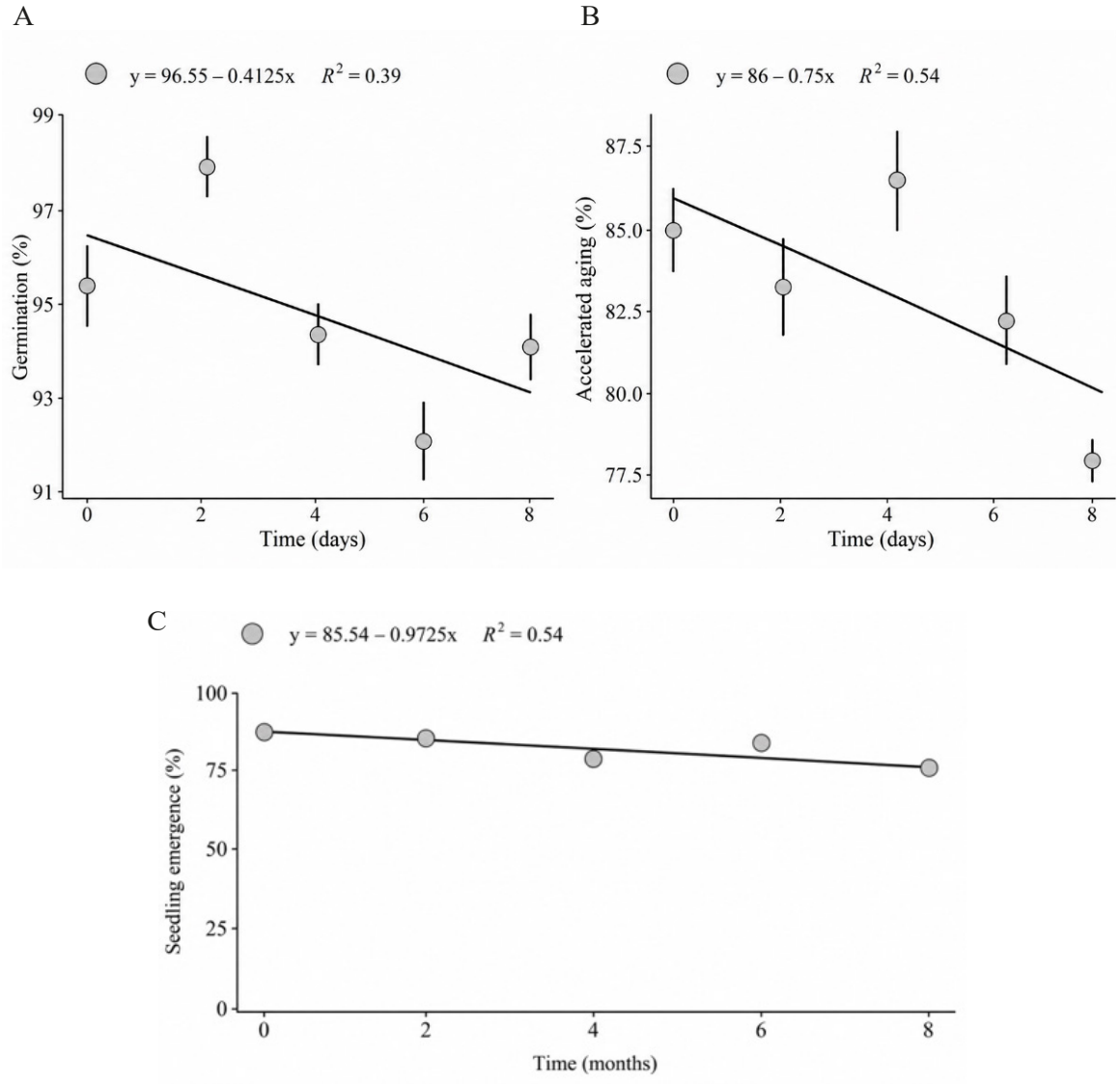


Figure 7. Germination (%) (A), accelerated aging (%) (B), and seedling emergence (%) (C) of grain oat seeds of the cultivar URS Corona stored under conventional warehouse conditions (CW) for eight months.

Combined analysis of cultivars

Principal component analysis (PCA) was performed using the mean values of the cultivars IPR Afrodite, IPR Andrômeda, and URS Corona for the evaluated physiological and physical variables, aiming to investigate the multivariate relationships among seed quality attributes and storage environments (Figure 8).

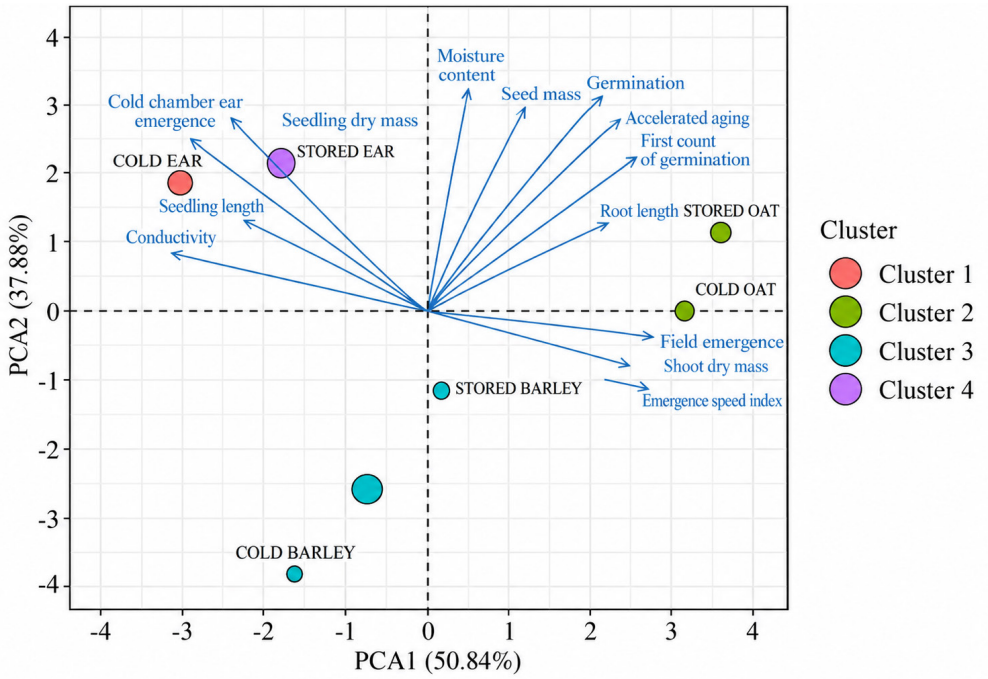


Figure 8. Biplot of the principal component analysis (PCA) of storage environments for the three grain oat cultivars. TSW: Thousand-seed weight; MC: Moisture content; GERM: Germination; FGC: First germination count; AA: Accelerated aging; RTL: Root length; SHL: Shoot length; RDM: Root dry matter; SDM: Shoot dry matter; SEM: Seedling emergence; ESI: Emergence speed index; EC: Electrical conductivity. AFRO-CW: IPR Afrodite under conventional warehouse conditions; AFRO-CC: IPR Afrodite under cold chamber conditions; ANDRO-CW: IPR Andrômeda under conventional warehouse conditions; ANDRO-CC: IPR Andrômeda under cold chamber conditions; CORO-CW: URS Corona under conventional warehouse conditions; CORO-CC: URS Corona under cold chamber conditions.

The first two principal components explained 88.72% of the total variance (PC1 = 50.84%; PC2 = 37.88%), indicating a high degree of model representativeness. PC1 was primarily associated with shoot dry mass, seedling emergence, and emergence speed index, contributing to the vertical separation of treatments. PC2 was mainly related to root dry mass, shoot length, and electrical conductivity, contributing to the horizontal separation of treatments.

The biplot revealed distinct responses among cultivars to storage conditions. IPR Andrômeda was positioned farther from the quality-related variables, suggesting lower sensitivity to storage conditions. URS Corona was associated with electrical conductivity, shoot length, and root dry mass, suggesting a greater impact of storage on its physiological quality.

IPR Afrodite exhibited an intermediate response, with performance primarily associated with shoot dry mass, seedling emergence, emergence speed index, and root length.

Discussion

The storage systems evaluated did not affect germination or seedling emergence of grain oat seeds, indicating that both conventional warehouse storage and cold chamber storage were effective in maintaining seed viability throughout the study period. A contrasting result was reported by Silva (2021), who observed a significant reduction in germination and emergence of soybean seeds stored without temperature or humidity control compared with those stored under refrigerated conditions.

Regarding the effect of storage duration, a reduction in germination was observed only in the cultivar URS Corona, indicating greater sensitivity to storage duration. Similar results were reported by Dostatny et al. (2015), who found a decline in *Avena fatua* germination as storage duration increased. For the cultivars IPR Afrodite and IPR Andrômeda, germination remained above the minimum standards required for commercialization, corroborating the findings of Padia (2020), who reported stable germination across packaging types and storage conditions. The influence of dormancy, reported by S. R. Pereira et al. (2009) as a factor contributing to initial variation in oat seed germination, was not observed in the present study, and dormancy-breaking treatments were therefore unnecessary.

The vigor tests showed distinct responses among cultivars, confirming that vigor assessments are more sensitive than germination tests for detecting physiological differences among seed lots with similar germination performance (Marcos Filho, 1999). Among these tests, accelerated aging revealed a progressive reduction in vigor throughout the storage period, with superior preservation observed for approximately 4 months under cold chamber storage only for the cultivar IPR Afrodite. A similar trend was reported by Pasinato et al. (2017) in black oat seeds, in which vigor declined after 135 days of storage, indicating deterioration. This behavior can be attributed to the fact that the germination test is conducted under optimal conditions, whereas the accelerated aging test exposes seeds to adverse temperature and humidity conditions that simulate stressful field environments (Marcos Filho, 1999, Torres & Marcos Filho, 2001).

The emergence speed index was not affected by storage environment or duration, unlike the findings of R. C. Pereira et al. (2020), who reported superior performance in soybean seeds stored under refrigerated conditions.

Electrical conductivity indicated an increase in seed deterioration as storage progressed, reflecting greater disorganization of cell membranes and the consequent leakage of electrolytes, a phenomenon characteristic of seed aging (Marcos Filho, 2015). Similar results were reported by Couto et al. (2021) in soybean seeds. The increase in electrical conductivity may also be associated with higher moisture content, which promotes metabolic activity and accelerates cellular degradation (Alencar et al., 2008), a relationship observed in the present study as well.

Variations in moisture content throughout storage are related to the hygroscopic nature of seeds and to fluctuations in ambient temperature and

relative humidity (Vanier et al., 2018). According to Pohndorf (2012), these fluctuations result from the hygroscopic equilibrium established between the stored product and the surrounding air through exchanges of heat and water vapor, which explains the distinct patterns observed among the storage systems.

For thousand-seed weight, reductions were observed in several storage environment × cultivar combinations throughout the storage period. Similar behavior was reported by Tunes et al. (2010) for barley seeds and by Carneiro (2003) for wheat seeds, who attributed this reduction to dry-matter losses due to respiration and deterioration.

Shoot and root length increased initially, then declined after 4 months of storage, a pattern similar to that reported by Dan et al. (2010) for soybean seeds. In contrast, Tunes et al. (2010) found no effect of storage environment on seedling length in barley, suggesting that this variable may respond differently across species and genotypes.

Seedling dry mass decreased throughout the storage period in all three cultivars, indicating reduced growth potential. This result differs from that reported by Peixoto and Barbosa (2012), who observed no changes in this variable in forage radish seeds. This discrepancy reinforces that the rate of deterioration and its physiological consequences vary according to genetic characteristics and storage conditions.

Overall, although the storage systems did not compromise the viability of grain oat seeds during the eight-month evaluation period, progressive changes were observed in vigor-related attributes, particularly as a function of storage duration and genotype. The maintenance of germination and seedling emergence indicates that both conventional warehouse storage and cold chamber storage were effective in preserving seed germinative potential. However, reductions in seed vigor were detected by more sensitive tests, such as accelerated aging, electrical conductivity, shoot and root length, and seedling dry mass, demonstrating that the deterioration process occurs gradually and can be detected before affecting standard germination. The cultivar URS Corona's greater sensitivity to storage conditions is also noteworthy, reinforcing the influence of genetic factors on the preservation of seed physiological quality.

The decline in seed quality during storage was reflected in increased electrical conductivity, fluctuations in moisture content, reductions in thousand-seed weight, and decreased initial seedling growth. These results confirm that monitoring vigor tests is essential for detecting physiological changes that are not revealed by the germination test. Therefore, although both storage environments preserved the commercial viability of the seeds, cold chamber storage provided greater stability for certain vigor-related variables, particularly during the initial months of storage.

Therefore, it can be concluded that the response to storage is dependent on both genotype and environmental conditions, highlighting the need for specific strategies to maximize the preservation of physiological quality in grain oat seeds.

Conclusions

The storage systems evaluated (conventional warehouse and cold chamber) were effective in maintaining germination and seedling emergence of grain oat seeds, preserving seed viability throughout the eight-month storage period.

The effect of storage is genotype-dependent, with the cultivar URS Corona being more sensitive to deterioration than the cultivars IPR Afrodite and IPR Andrômeda.

Seed vigor declines during storage in the cultivars URS Corona and IPR Afrodite.

Storage under conventional warehouse conditions promotes dry matter loss from the fourth month onward, as reflected by reductions in thousand-seed weight and seedling dry mass across all cultivars evaluated.

Cold chamber storage provides greater stability for vigor-related variables, particularly during the initial months of storage.

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